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INVESTIGATION OF REMOTE SENSING TECHNIQUES AS INPUTS TO OPERATIONAL RESOURCE MANAGEMENT MODELS

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Participating South Dakota State Government Agencies include the State Planning Bureau, the Department of Game, Fish and Parks, the Department of Natural Resources Development and the Black Hills Conservancy Subdistrict.

16. Abstract LANDSAT and aircraft remotely-sensed data are being evaluated by South Dakota Government Agencies as potential data sources for present operational state programs. Emphasis is placed on procedures which can be easily initiated using present state government restraints. The study site is the 824,000 hectare (2,035,000 acre) Belle Fourche River Basin in western South Dakota. Evaluation of a NASA-developed LANDSAT CCT rectification program is reported. Land use studies center on determining optimum date for Level 1 visual LANDSAT interpretations. LANDSAT surface water inventory capabilities (visual and digital) are also being evaluated. LANDSAT CCT's, in conjunction with DIRS have been investigated for aspen mapping and crop identification. Drainage analysis, using combinations of 1:24,000 USGS Quadrangle maps, high altitude photography and LANDSAT imagery, has been conducted and has resulted in an operational mapping program for western South Dakota. Entry of resource management data into a computerized data base is also under investigation.

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PREFACE

This is the fifth quarterly report on an 18-month resource management study funded through the NASA LANDSAT follow-on activity. The primary objective of the study is to assist participating state agencies evaluate remote sensing (with emphasis on unmanned resource satellite data) as a cost-effective data source in operational programs. Participating South Dakota agencies include: The Black Hills Conservancy Sub-district, the State Planning Bureau, the Game, Fish and Parks Department, and the Department of Natural Resources Development. With the exception of the Subdistrict, each agency has committed half a man-year to the project. In this way remote sensing training and evaluation of useful data products is enhanced. With NASA high altitude aircraft imagery, low-altitude aircraft data, and ground truth information, LANDSAT satellite data are being evaluated as a data source for such programs as land use mapping, surface water inventories, aspen mapping, and crop identification. Both visual and computerized interpretive techniques are being investigated. Also under investigation is a NASA-developed Digital Image Rectification System (DIRS) which rectifies LANDSAT multi-spectral scanner digital tape data using Universal Transverse Mercator coordinates as the base grid. The DIRS package will be evaluated for cost effectiveness as well as for the potential of improved digital data analyses. Resource data handling is being addressed via MAPCLASS, a program which provides a method of data storage and handling with output via line printer, color television monitor, and/or CALCOMP plotter. Basic project results will provide recommendations on the operational use of LANDSAT data for South Dakota State government.

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INTRODUCTION

This is the fifth quarterly report of LANDSAT Follow-On Project, NASA Contract NAS5-20982. LANDSAT and aircraft remotely-sensed data are being evaluated by three South Dakota governmental agencies: the Game, Fish and Parks Department (GF&P), the State Planning Bureau (SPB), and the Department of Natural Resources Development (DNRD). Remote sensing data and associated interpretive techniques are being studied to determine input applicability to present operational state programs. Emphasis is placed on procedures which can be easily initiated using present state government financial and personnel restraints. The study site is the 824,000 hectare (2,035,000 acre) Belle Fourche River Basin in western South Dakota. Interpretations reported herein center around land use evaluations, surface water mapping and aspen delineation using LANDSAT imagery. An MSS CCT rectification program is also being evaluated.

PROBLEMS

Late delivery of initial aircraft and LANDSAT data products did not allow for tasks to be accomplished according to the proposal schedule. It is felt that substantial contributions remain and a request has been made through the NASA Technical Monitor to extend the project. The extension is necessary to ensure completion of the project as proposed. Tentative verbal confirmation of the extension has been received from the Technical Monitor.

ACCOMPLISHMENTS

Digital Image Rectification System

One of the major advantages of rectifying LANDSAT CCT data is the resultant potential for sequential computer data assessment. The digital analysis of rectified CCT's might allow automatic comparison of surface water inventories at different time periods. Monitoring of crop reflectance and knowledge of area crops might assist in accurate areal crop identification. The potential for automatic mapping and monitoring of resources (such as aspen) is well within the possible uses of rectified LANDSAT CCT data. Necessary for such work is a method of reducing the distortions inherent in the CCT's as supplied by EROS. NASA has developed a rectification program package specifically for "correcting" LANDSAT data. The Remote Sensing Institute obtained the NASA-developed programming package called Digital Image Rectification System (DIRS). DIRS was designed to operate on digital LANDSAT MSS imagery and to cartographically correct the data to a Universal Transverse Mercator (UTM) grid system (1).

Preliminary work was begun during the last quarter (2). Selection of approximately 20 ground control points (GCP) per scene is recommended (1). The GCP's are geographic or physiographic landmarks which can be found on the LANDSAT image and on 1:24,000 USGS Quadrangle maps. After the GCP's are selected and the approximate pixel coordinate for each GCP is established, DIRS produces a shade print of the GCP area. The print is used for verification of the GCP location. The pixel coordinates obtained from the shade print are used as input to the next DIRS step which provides for expansion of the MSS data

at the GCP site. These expanded maps are used in conjunction with 1:24,000 Quad maps to correlate the USGS and DIRS GCP coordinates. In some areas of western South Dakota there are no 1:24,000 maps available. In other cases, the 1:24,000 maps have no UTM coordinates. These facts must be kept in mind while selecting GCP's.

With the coordinate input, DIRS generates data that are used for the rectification of an entire scene or portions thereof. To date LANDSAT scenes E-2186-17004 and E-2222-16595 have been processed using DIRS. Preliminary evaluation of the rectification/overlay accuracies of the program has begun. Initial work with DIRS revealed that considerable technician time is required in the processing of GCP's. Selection of points, working with the various printouts and determining coordinates was not a minor consideration for the first CCT to be rectified. Subsequent rectification of scenes over the same area allowed duplication of GCP's and associated UTM coordinates. Based on these procedures approximately 5 man-days are required for 10 GCP's. As techniques are developed and refined this time estimate may be revised. Based on technician wage of \$10/hr the labor costs for a scene would be about \$400. Computer rectification costs for CCT E-2222-16595 are summarized in Table 1. The "Definition of Rectification parameters" step calculates the data necessary to actually rectify specific areas within a scene or the entire scene. In an aspen mapping study, a 93 km^2 (36 mi^2) area was rectified and line printed for an average cost of \$.07/km^2 (\$.17/mi^2).

Total costs can be summarized as in Table 2. One of the major advantages of rectifying LANDSAT data is the resultant potential for

TABLE 1. COMPUTER RECTIFICATION COSTS FOR SCENE E-2222-16595 USING DIRS, 70m PIXEL AND TEN GCP'S; IBM 370 MODEL 145 COMPUTER

DIRS Step	Computer Costs Incurred
Shade Print	$ 96.20
Cubic Convolution Expansion	183.00
Definition of Rectification Parameters	3.75
Subtotal	$282.95

TABLE 2. TOTAL COSTS FOR DIRS RECTIFIED LANDSAT CCT USING 10 GCP's, 70m PIXEL RESOLUTION

	Cost For:	
	Window	Entire Scene
Computer Costs	\$300	\$300
Technician Time	\$400	\$400
Rectified Line Printer Output Data	\$.07/km^2*	\$100**

* Based on actual data; includes line printout
** Based on estimated data, does not include line printout

sequential computer data assessment. Necessary for such work is an overlay capability of sequential LANDSAT data. Such overlay capability will allow monitoring of specific points on the ground, on a temporal basis, by permitting pixel-for-pixel overlay in a time-sequential period limited by cloud conditions and LANDSAT orbit configurations. To evaluate DIRS output for such requirements, a series of geographic accuracy test points have been selected. For inclusion as a test point, an object must be identifiable both on the 1:24,000 Quadrangle map and on the DIRS-rectified output. A point is selected and the latitude and longitude is determined from the base map. A four minute by four minute window surrounding the point is extracted from the CCT and processed using DIRS. Knowing the window boundary latitude and longitude and spotting the test point on the printout allows calculation of the DIRS-generated latitude and longitude by simple scale measurements and ratioing. The geometric accuracy test points thus far evaluated are listed in Table 3. Additional test points are planned. To assist in evaluating the information contained in Table 3, the differences in combinations of latitude/longitude are presented in Table 4.

It should be reiterated that identical GCP's and UTM coordinates were used for the July and September CCT's. There are two basic reasons for this: 1) decreased costs involved in GCP processing and 2) ability to enhance potential overlay capabilities of the rectified output. It was felt that the spatial accuracy of DIRS coordinates as compared to base map coordinates was not as important, from a sequential CCT analysis point of view, as was overlay capabilities of various LANDSAT

TABLE 3. LATITUDE AND LONGITUDE OF DIRS - GENERATED GEOGRAPHIC ACCURACY TEST POINTS AS COMPARED TO BASE MAP COORDINATES

Test Point No.	USGS Base Map		July CCT		Sept CCT	
	Lat	Long	Lat	Long	Lat	Long
1	44°18'42"	103°35'00"	44°18'44"	103°35'02"	44°13'43"	103°35'00"
2	44°13'26"	103°22'05"	44°13'27"	103°21'56"	44°13'26"	103°21'55"
3	44°09'31"	103°07'12"	44°09'37"	103°07'09"	44°09'35"	103°07'08"

TABLE 4. COMPARATIVE COORDINATE DATA FOR BASE MAP AND DIRS RECTIFIED LANDSAT CCT'S.

Test Point No.	(USGS - July CCT)		(USGS - Sept CCT)		(Jul - Sept)	
	Lat	Long	Lat	Long	Lat	Long
1	2"	2"	1"	0"	1"	2"
2	1"	9"	0"	10"	1"	1"
3	4"	3"	4"	4"	2"	1"
average (sec.) (Meters)	2.3" (70)	4.7" (104)	1.7" (52)	4.6" (102)	1.3" (40)	1.3" (29)

scenes. Use of identical GCP's and associated UTM coordinates should maximize the overlay efficiency of DIRS.

Again, Table 4 is not complete as a larger number of test points remain to be examined. The averages are not of much statistical validity considering the small sample, but they may indicate a trend in accuracies. Considering the 70 m x 70 m DIRS pixel dimension, the average errors in overlaying July and September data appear encouraging (40 m latitude and 29 m longitude) or, less than the specified DIRS pixel. Continued analysis of other CCT's, additional GCP's, geometric accuracy test points and costs should allow basic conclusions to be drawn regarding DIRS applicability.

DIRS output is not north oriented, i.e. line printer and plotter maps are rectified but remain rotated approximately 12 degrees west of north. This is not a serious problem in classification work but it is a restraint to the potential automatic entry of data into a data base like MAPCLASS. Development of a rotation routine is desirable but not within the scope of this project.

Land Use

All participating state agencies have expressed interest in evaluating various land use data sources. Game Fish and Parks (GF&P) and the Department of Natural Resource Development (DNRD) are under legislative mandate to provide resource inventories of each of the state's 16 river basins every four years. One of the most important resources in South Dakota is the land itself. Detailed information regarding its use and the spatial distribution of the various uses is considered as significant input for these four-year surveys. The State Planning

Bureau (SPB) is preparing a landuse map of the state using digital analysis of LANDSAT MSS CCT data. The Bureau is interested in evaluating the digital analyses with results obtained from other data sources.

Historically, land use information has been obtained from a variety of sources including the Conservation Needs Inventory and Crop and Livestock Reporting Service Reports. Usually the data are not subdivided into river basins but into political subdivisions such as counties. This procedure results in estimating errors as the data are manipulated to a river basin status.

To assist in the evaluation of the accuracies of LANDSAT interpretations, an area which contained a good selection of cloud-free LANDSAT and high altitude imagery was chosen. The site, a ten-township 230,400 acre (93,279 hectare) area, is located north and east of Sturgis in the center of the basin.

Two dates of high altitude coverage are available for the site. Interpretations of color infrared transparencies produced the agricultural percentages listed in Table 5. The discrepencies between the two interpretations will be discussed later.

TABLE 5. HIGH ALTITUDE AIRCRAFT INTERPRETATION

Data Source	Date	Scale Interpreted	Percent Agricultural Land
High-altitude Color IR	25 Jun 75	114,506	27
High-altitude Color IR	23 Sep 75	125,880	22

A variety of LANDSAT data are available and interpretations have been conducted as listed in Table 6. Sufficient data were available to allow representation of each of the months May through November. Additional input from DNRD and GF&P interpreters is expected.

Optimum interpretations would result in 100 percent of the RB-57 agricultural lands (in terms of total area) being interpreted. However, selection of optimum dates for interpretation should not be based on such information alone. Spatial accuracies were determined for the interpretations as indicated and include the optimum (gross accuracy) interpretation available for May through November.

The spatial accuracy data are listed in Table 7. Rangeland is consistently interpreted as rangeland approximately 90 percent of the time throughout the season. Agricultural land interpretations are much more variable. It appears from the data in Table 7 that a prime date for interpreting agricultural land from LANDSAT for western South Dakota, is in the mid June to late July growing season.

Referring to Figure 1, a Belle Fourche Basin crop calendar, the mid June to July period intersects most crops in LANDSAT-recognizable stages of development. Small grains are heading and ripening, identifiable as red or yellow patterns, respectively on a color composite. Corn and sorghum can be identified as either a bare field shortly after planting or as a bright red color as the plants grow and mature. Alfalfa is identifiable with a very bright red signature. Wild hay areas, which, for this interpretation would be considered agricultural, are interpreted only after cutting and then as a pattern within the predominantly range areas.

TABLE 6. COLOR COMPOSITE INTERPRETATIONS FOR 10-TOWNSHIP AREA.

Date	Scale	Source*	Ag. land as a percent of interpreted RB-57 Ag. land
24 May	1:125,000	E-P (DNRD)	65
24 May	1:125,000	E-P	104**
24 May	1:125,000	R-P	123
12 June	1:125,000	E-P	93**
18 July	1:125,000	E-P	134
27 July	1:250,000	ZTS	126
27 July	1:125,000	ZTS	130**
27 July	1:250,000		130
27 July	1:250,000	E-P (DNRD)	56
27 July	1:125,000	E-P	111**
27 July	1:125,000	R-P	102**
27 July	1:125,000	E-P (DNRD)	100**
5 August	1:125,000	E-P	95**
23 August	1:125,000	E-P	96**
1 September	1:125,000	E-P	100**
1 September	1:125,000	R-P	81
October	1:125,000	E-P	51
November	1:125,000	E-P	73

* E = EROS Color Composite
R = RSI Color Composite
P = Print
ZTS = Zoom Transfer Scope

** Accuracy %'s calculated

TABLE 7. LANDSAT INTERPRETATION BREAKDOWN (as compared to RB-57 ground truth) FOR BEST DATA IN EVERY MONTH EVALUATED FOR SPATIAL ACCURACY.

Date	Ag. Land as Ag. Land	Ag. Land as Range	Range as Range	Range as Ag.	Avg. Accuracy $\frac{[A/A+R/R]}{2}$
24 May	75.9	24.1	90.1	9.9	81.6
12 Jun	83.8	16.2	93.6	6.4	88.7
27 Jul	84.0	16.0	91.2	8.8	87.6
5 Aug	72.6	27.6	92.3	7.7	82.4
1 Sep	68.5	31.5	89.2	10.8	78.8
Nov	51.5	48.5	92.7	7.3	72

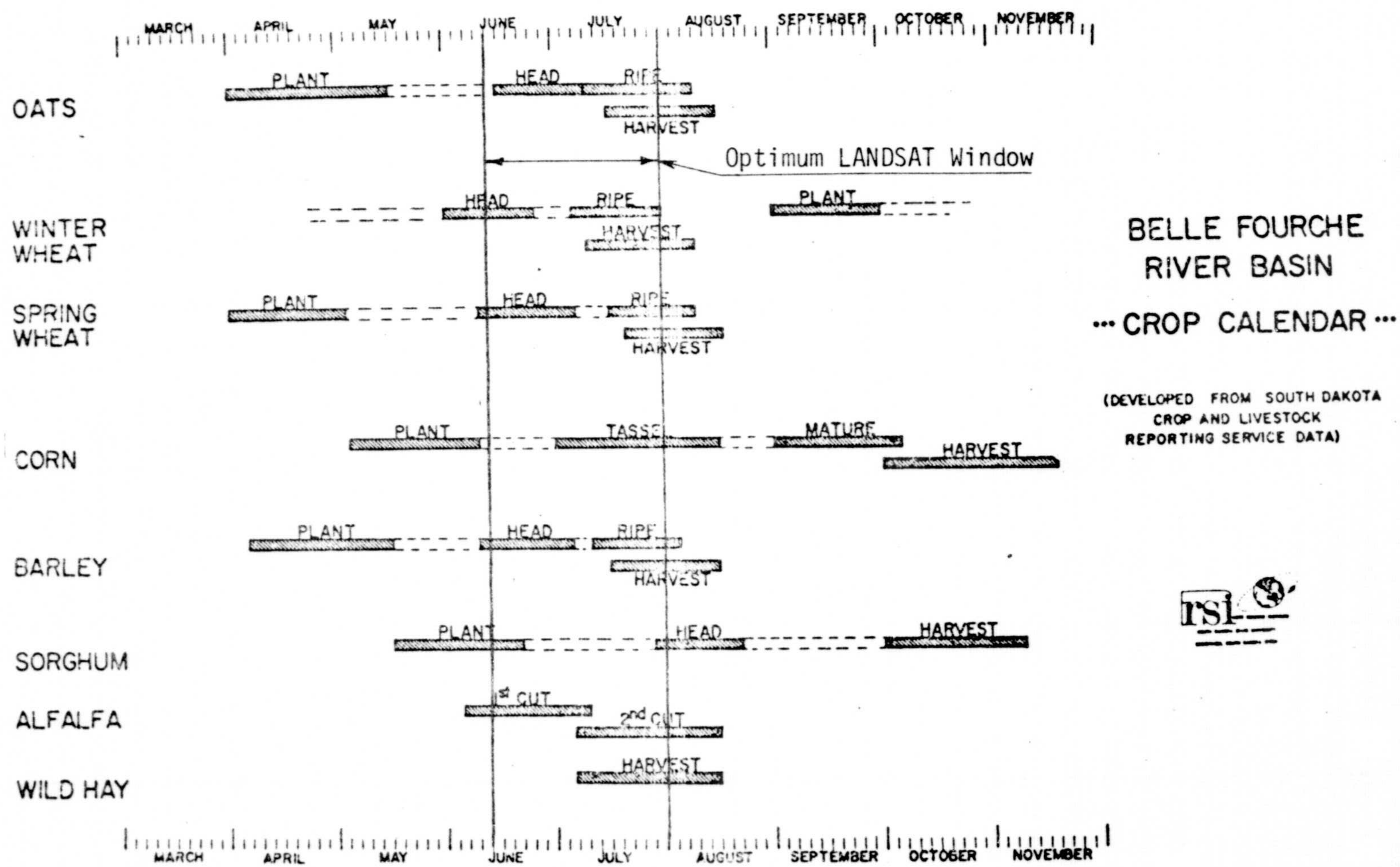

Figure 1. Crop calendar for the Belle Fourche River Basin with optimum LANDSAT Level I Land use window indicated.

Interpretation accuracies for three sets of black and white interpretations (2) are presented in Table 8. Additional interpretations will be conducted prior to project completion.

Comparison of June RB-57 and September U-2 interpretations resulted in an interesting observation. If it is accepted that the two initial data sets were of comparable quality, a loss of five percent in the overall agricultural areas is noticed in the September interpretation. Spatial comparison with June RB-57 data is seen in Table 9. It is

TABLE 9. SPATIAL COMPARISON OF SEPTEMBER HIGH ALTITUDE AIRCRAFT DATA WITH JUNE HIGH ALTITUDE AIRCRAFT DATA

Ag as Ag	Ag as Range	Range as Range	Range as Ag*
76.4	23.6	97.1	2.9

* Includes 720 acres of new agricultural land as rangeland interpreted as agricultural.

suggested that the 24 percent agricultural land classified as rangeland from the September interpretation is a result of land cover changes as the season progresses. There are a number of interpretive guides used to assist in classifying land into the agricultural category from high altitude imagery. Color, texture and patterns all assist and if classification remains in doubt, the apparent resolution of the film allows recognition of detailed information such as haystacks, cutting and cultivating patterns, etc. In the June interpretation, all of these interpretive devices could be used. By September, color differences are reduced substantially and the interpretation was heavily based on other indicators. Certain pasture areas in particular were

TABLE 8. PERCENTAGE INTERPRETATION BREAKDOWN (as compared to RB-57 data) FOR B&W LANDSAT DATA EVALUATED FOR SPATIAL ACCURACY.

Data Source	Ag Land as Ag Land	Ag Land as Range	Range as Range	Range as Ag	Avg. Accuracy $\frac{A/A + R/R}{2}$
24 May MSS5+7	70.7	29.3	92.6	7.4	86.7
12 Jun MSS5	77.5	22.5	91.6	8.4	84.5
27 Jul MSS5+7	82.9	8.7	91.3	17.1	81.1

unidentifiable without the color differentiation present in the June imagery. As LANDSAT interpretations must rely soley on the color/pattern signatures, it is reasonable to expect an increase in LANDSAT-based classification of agricultural land as range (Table 7) as the season progresses. It is important, then, to obtain ground truth (i.e. aerial photography) during the time frame also designated for optimum satellite interpretation.

Surface Water

Analysis of interpretive scales and data sources was initiated to provide a basis for recommendations regarding LANDSAT as a surface water inventory tool. While surface water is a category in Level I land use, it is handled separately here. To be classified in a Level I land use classification, the surface area must equal or exceed 40 acres (16 (16 ha). In western South Dakota there are numerous bodies of water which are considerably less than 16 hectares. The number and distribution of these smaller bodies of water are important in evaluating the general water (and soil moisture) conditions throughout the basin. The small water bodies are also important to western South Dakota fisheries management, wildlife and livestock production. To inventory only 16 ha and greater surface water bodies, as specified in Level I Land Use, would place serious restrictions on the reliability and usefulness of the surface water inventory. For these reasons, surface water is separated from the Level I Land Use category and the surface water inventory capabilities of LANDSAT are separately investigated in detail.

The same 10-township area used in land use analysis is being used for surface water studies and can be seen in Figure 2. Initial interpretations were concerned with a strictly numerical accounting of bodies of water within the 10-township area. A variety of data sources were employed and are listed in Table 10. A number of interpretations have been added since the last quarterly report (2).

An ASCS photo interpretation was prepared by DNRD. This source was included because DNRD has interpreted surface water from such photographs for the entire state and the Department is interested in comparing the results of their present procedures with what might be available via LANDSAT. The comparative inventory value (4) of the ASCS interpretation is better than most LANDSAT values. But, when the interpretation is more closely analyzed (within the smaller area of Fig. 2), the apparent advantage over LANDSAT is not so pronounced.

Referring to Table 11, the ASCS interpretation resulted in 77 percent identification of water bodies over 1.1 acres (.45 ha). Interpretations of MSS7 data produced "above 77 percent" figures in all but four LANDSAT Visual interpretations. The ASCS data were more adequate than LANDSAT for interpreting the less than 1.1 acre water bodies. The apparent resolution of the imagery is offered as explanation. The descrepencies between LANDSAT and ASCS interpretations of > .45 ha data might be the result of interpretive variabilities, the fact that the ASCS data are nearly ten years old, and, the fact that the ASCS imagery was collected in July, a potentially dry period.

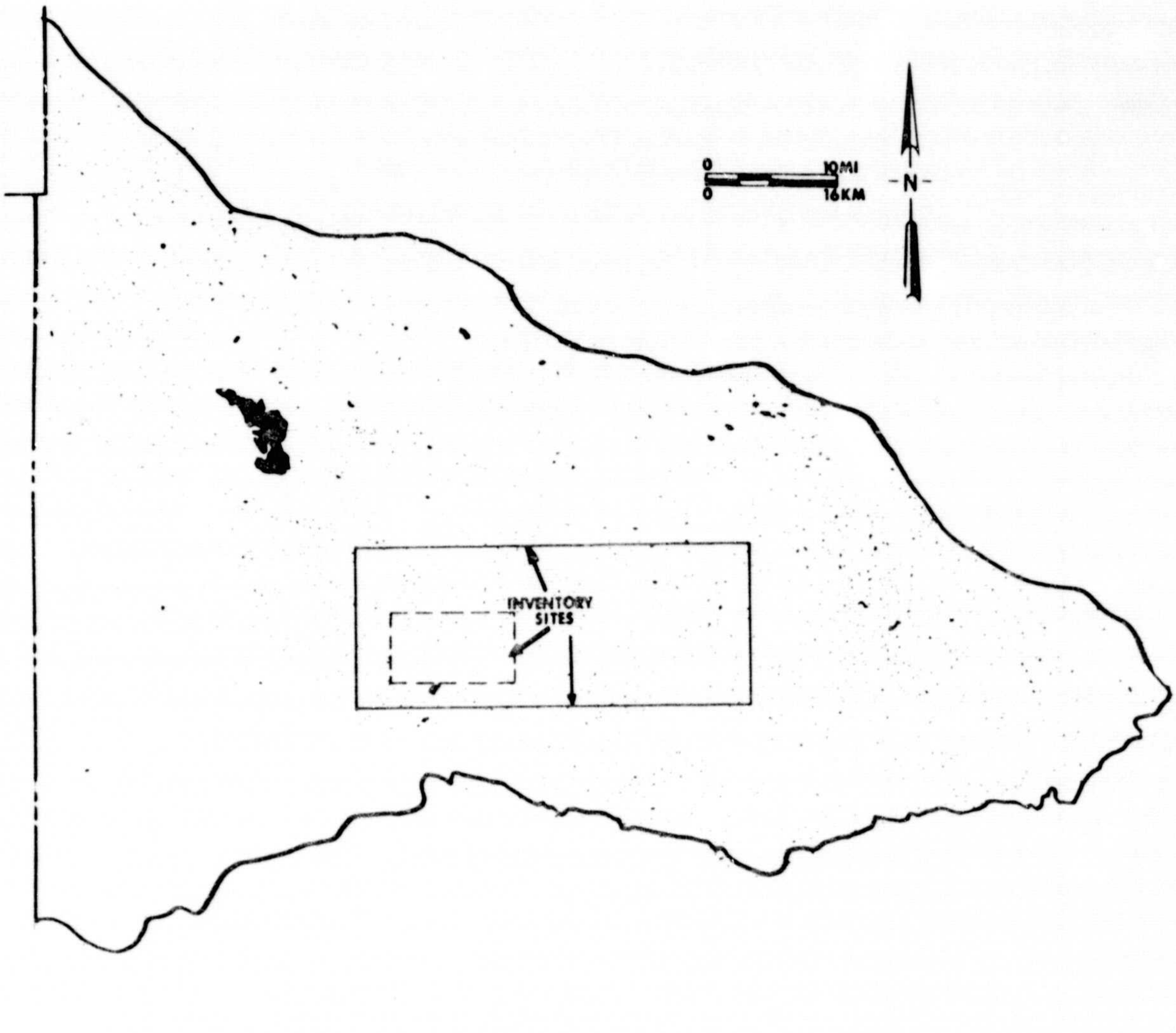

Figure 2. Surface water interpretation of the Belle Fourche River Basin as interpreted by DNRD personnel from spring 1975 LANDSAT MSS 7 imagery. Visual print interpretation was conducted at 1:250,000. The larger rectangular area is a ten-township site interpreted for water bodies from a variety of data sources. The smaller outlined area was interpreted with more detailed evaluation of LANDSAT inventory capabilities.

TABLE 10. SURFACE WATER INTERPRETATIONS FOR 10-TOWNSHIP TEST AREA (Townships 6 and 7 North)

Data Source	Interpreter No.	Data Date	Scale Interpreted	No. Water Bodies	Comparative Inventory Value
High Altitude Color IR Transp.	1	25 Jun 75	1:114,506	652	1.00
High Altitude Color IR Transp.	1	23 Sep 75	1:125,880	591	.91
LANDSAT MSS7; ZTS	1	12 Jun 75	1:250,000	488	.75
LANDSAT MSS7; Print	1	12 Jun 75	1:125,000	402	.62
LANDSAT MSS7; Print	1	24 May 75	1:125,000	380	.58
LANDSAT MSS7; Print	1	27 Jul 75	1:125,000	222	.34
LANDSAT MSS7; Print	2	12 Jun 75	1:250,000	273	.42
LANDSAT MSS7; Print	2	12 Jun 75	1:125,000	302	.46
LANDSAT MSS7; Print	2	24 May 75	1:125,000	282	.43
LANDSAT MSS7; Print	3	12 Jun 75	1:250,000	343	.52
LANDSAT MSS7; Print	3	12 Jun 75	1:250,000	266	.41
LANDSAT MSS7; Print	3	12 Jun 75	1:125,000	645	.99
LANDSAT MSS7; Print	3	24 May 75	1:125,000	688	1.05
ASCS Mosaic; Print	3	Jun/Jul 68	1: 64,985	512	.79
Township 6 North only:					
High Altitude Color IR Transp.	1	25 Jun 75	1:114,506	274	1.00
LANDSAT MSS7; Print	1	27 Jul 75	1:125,000	102	.37
LANDSAT MSS7; CCT	4	27 Jul 75	N/A	105	.38

TABLE 11. DETAILED SURFACE WATER ANALYSIS

Data Source	Interpreter No.	Data Date	Scale	Total No. Water Bodies	Percent Of Total Which Is Not Water	Percent of Base Data Interpreted	
						≤1.1 acre (.45 ha)	>1.1 acre (.45 ha)
High Altitude Color IR Transp.	1	25 Jan 75	1:114,506	146	0	100 Base Data	100
High Altitude Color IR Transp.	1	23 Sep 75	1:125,880	113	8	49	98
LANDSAT MSS7; ZTS	1	12 Jun 75	1:250,000	90	36	5	82
LANDSAT MSS7; Print	1	12 Jun 75	1:125,000	86	26	11	83
LANDSAT MSS7; Print	1	24 May 75	1:125,000	74	11	21	74
LANDSAT MSS7; Print	1	27 Jul 75	1:125,000	38	8	1	52
LANDSAT MSS7; Print	2	12 Jun 75	1:250,000	54	13	3	70
LANDSAT MSS7; Print	2	12 Jun 75	1:125,000	56	5	4	76
LANDSAT MSS7; Print	2	24 May 75	1:125,000	66	11	9	78
LANDSAT MSS7; Print	3	12 Jun 75	1:250,000	58	14	4	71
LANDSAT MSS7; Print	3	12 Jun 75	1:250,000	64	11	4	83
LANDSAT MSS7; Print	3	12 Jun 75	1:125,000	114	38	15	89
LANDSAT MSS7; Print	3	24 May 75	1:125,000	139	44	21	92
ASCS Mosaic; Print	3	Jun/Jul 68	1: 65,985	100	23	31	77
LANDSAT MSS7; CCT	4	27 Jul 75	---------	35	23	0	42
USGS Quadrangle Map	1	1953	1: 24,000	119	24	55	70

A CCT of scene 2186-17004 was rectified and level-sliced for water using SPB-developed programming packages. Window selection allowed processing of T6N only of the ten township area depicted in Figure 2. Color infrared and LANDSAT print interpretations were obtained for T6N and are listed along with the digital data in Table 10. The visual and digital procedures appear quite similar in relation to the base high-altitude data. Detailed analysis of the smaller area of Figure 2 (Table 11) indicates threshold values were not low enough to allow detection of any less than .45 hectare water bodies. Program capabilities are big developed which would allow detection of these smaller bodies.

Within the smaller area of Figure 2, 49 bodies of water interpreted both on RB-57 ground truth and LANDSAT MSS7 were used in estimation of water surface area from visual LANDSAT interpretations. The resultant data are found in Table 12. Area measurements of high altitude aircraft imagery were accomplished using 1:24,000 enlargements and a grid method. LANDSAT interpretation areas were estimated by visual comparison of the interpreted dot with the 40 acre grid cell used in digitizing for MAPCLASS. From the data it appears that surface water area is overestimated by .8 - 1.2 hectares per average water body using visual LANDSAT interpretation methods.

Table 13 provides low altitude aircraft data which is indicative of the seasonal variability of surface water referred to in the LANDSAT interpretations of the last quarterly report (2). For the interpreted sections of Table 13, both the total number of water bodies as well as total surface area has decreased from June to September. These

TABLE 12. SURFACE WATER AREA BY VISUAL ESTIMATE OF DOT SIZE COMPARED TO 40-ACRE (16.4 ha) CELL.

Data Source	No. Wtr. Bodies	Total Hectares	Average Hectare
RB-57*	49	62	1.3
LANDSAT-** RAPIDOGRAPH	49	115	2.3
LANDSAT-** SHARPIE	49	96	2.0

*Actual Areas
**Estimated Areas

TABLE 13. SURFACE WATER DATA FROM LOW ALTITUDE AIRCRAFT IMAGERY.

Sec. No.	June		Sep	
	No.	Hectares	No.	Hectares
21	7	1.6	7	1.1
28	11	.5	7	.6
20	15	4.6	13	2.8
27	6	12.8	5	12.5
TOTALS	39	9.5	32	17.0

data were further refined by subdividing the surface area measurements into categories as listed in Table 14. For the sections under consideration, the largest number of water bodies are less than .2 ha with a majority being less than .5 ha. The importance of inventorying these smaller water bodies and the ability of LANDSAT to conduct such an inventory will be addressed during the course of this project.

Crop Identification

LANDSAT color composite data of test area number six (3) were printed to a scale of 1:125,000. An attempt was made to identify fields within the ground truth area. Considerable visual inspection allowed the location of only the largest of the area fields. Within the Belle Fourche Irrigation District (which is where ground truth was collected) fields are not large, average sizes of 4.5 ha are not uncommon. These size fields were not easily recognized by visual interpretation of 1:125,000 color composite LANDSAT data.

An attempt at digital analysis of sequential CCT's using DIRS-rectified LANDSAT data again resulted in an inability to identify known fields. Shade prints of MSS5 and MSS7 for 27 July and 1 September were used in the analysis. Boundary-detection techniques could be employed to assist in field locations. However, from an operational point of view, it appears accurate LANDSAT-based crop identification on a river basin basis is not feasible at this time and additional work will not be emphasized.

TABLE 14. SIZE DATA ON SURFACE WATER FROM LOW ALTITUDE AIRCRAFT IMAGERY.

Size Class (Acres) [ha]	June		Sep	
	No.	Total Hectares	No.	Total Hectares
<.1 [<.04]	11	.2	10	.3
.1-.5 [.04-.2]	22	1.8	17	1.7
.5-1.0 [.2-.4]	2	.6	2	.6
1.0-2 [.4-.8]	1	.7	1	.5
2-5 [.8-2.0]	2	3.8	1	2.0
>5 [>2.0]	1	12.1	1	11.8
TOTALS	39	19.4	32	16.9

Drainage Systems

An interest was expressed in drainage networks and basin/sub-basin delineation. An accurate drainage map of the Basin is not in existence, so an effort was put forth to demonstrate and develop a procedure to produce such a map. The basic premise was to work from available 1:24,000 USGS Quads. The drainage information on quadrangle maps was considered as the optimum readily available data. Where quads were not available, high altitude aerial photography was designated as prime data source. Where neither quad nor aerial photography was available, LANDSAT imagery was prime data source.

The developed procedure is as follows. Transfer drainage information from 1:24,000 Quadrangle maps to velum. Where maps are unavailable, a ZTS and high altitude color infrared transparency are used to develop requisite drainage data. In areas where no aerial photography or drainage maps are available, drainage information is obtained from a combination of interpretation of winter black and white and summer color composite scenes. LANDSAT winter scenes accentuate certain drainage features via the combination effects of snowcover, and sunangle. In very flat areas the winter data is difficult to interpret. For these areas, the color composite provides drainage analysis indicators such as vegetation along stream and soil erosion signatures. A combination of the two seasons allows for the generation of a LANDSAT-based drainage map in areas devoid of other data.

All interpreted drainage data are photographed and printed to the same scale for preparation of a controlled mosaic. The mosaicked drainage map is then drafted as the final drainage map.

Continued analysis will allow comparison of LANDSAT-developed drainage data with that of 1:24,000 Quadrangle maps. Temporal overlays using I^2S (Model 6040 PT) is also contemplated.

The methods described above have resulted in similar work being conducted by RSI for the Sixth Planning District for seven western South Dakota counties. In addition to basic drainage mapping, basin/sub-basin delineations are interpreted and surface water is interpreted from LANDSAT MSS7 imagery. The resultant products, county-wide hydrology maps, are being prepared in this operational situation as a direct result of LANDSAT Follow-On Project developments.

Floodplain Analysis and Strip Development

Planning Bureau personnel have historically developed floodplain maps from existing contour maps. Using this procedure, development of flood high water mark has been an intuative procedure based on contour lines. The Bureau is in the process of evaluating high altitude aerial photography for flood plain analysis. A region surrounding Belle Fourche, South Dakota is being mapped for floodplain using two data sources: 1:24,000 USGS Quadrangle Maps and high altitude imagery.

Extensive private development along the "strip" area between Sturgis and Rapid City has prompted the State Planning Bureau to map the entire area for land use. A map of the Blackhawk Quadrangle is seen in Figure 3. The information was interpreted from 1975 high altitude transparencies using a Zoom Transfer Scope. Low altitude RSI imagery was viewed stereoscopically to verify any questionable classifications. An interpretation of 1974 imagery was available via NASA Office of University Affairs, Grant No. NGL 42-003-007 and

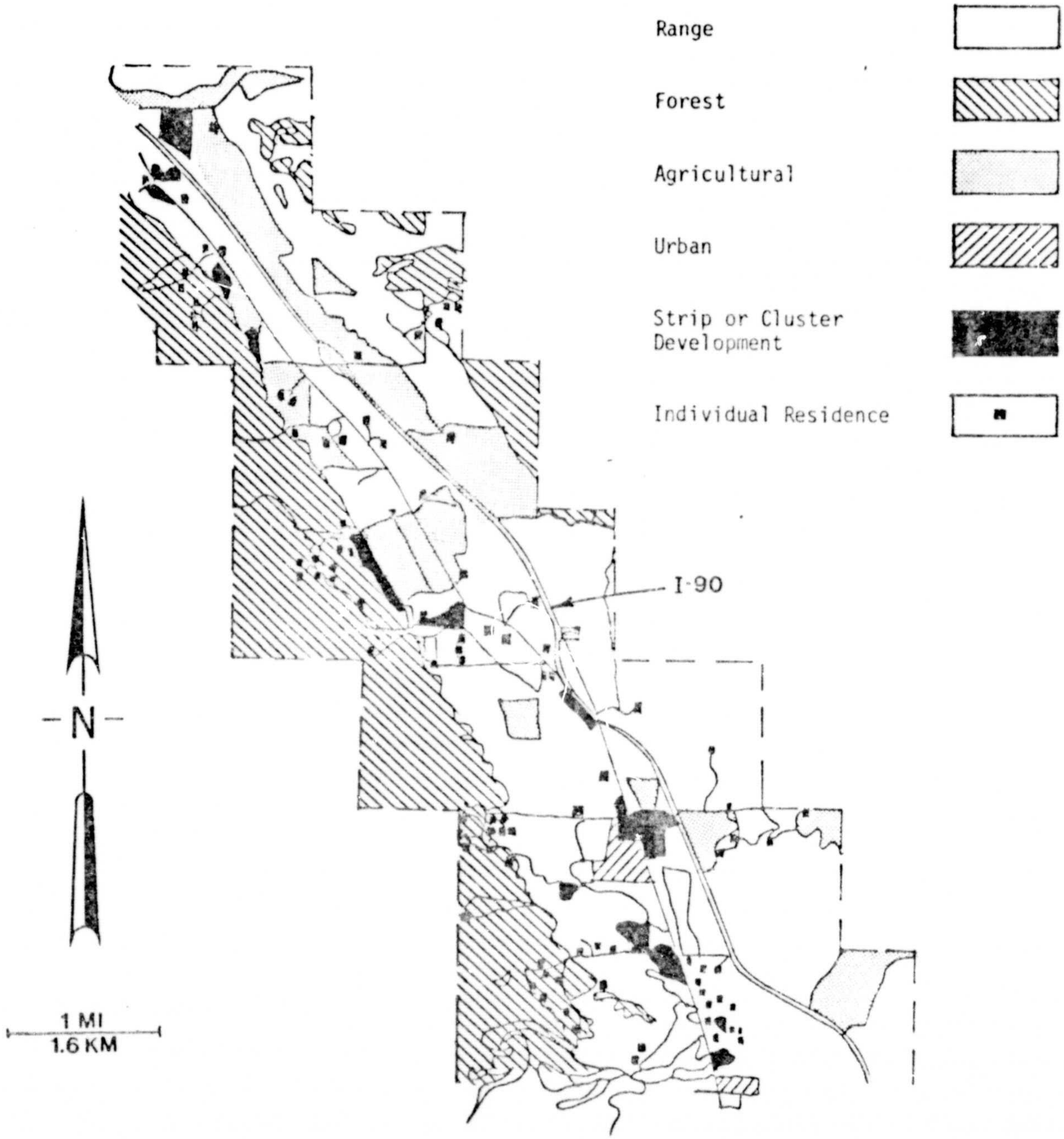

Figure 3. Landuse along Sturgis-Rapid City Strip area as interpreted from 1975 aircraft data.

is seen in Figure 4. Note the extensive development in the southern portion of the 1975 map as compared to the 1974. Development is so rapid that it is becoming a problem for local government officials. Remote sensing offers a potential method for monitoring the development.

Aspen

An aspen resource inventory of the Black Hills area has assumed added importance to GF&P personnel. The Department was involved in a study which indicated pulverized aspen to be a good cattle feed supplement. Black Hills aspen groves may now become an asset. Potential development includes planned harvesting of aspen for use as a feed supplement. Development of a method for locating and monitoring aspen groves resulted in GF&P initiation of this aspect of the project.

An area of representative forest types was located using high altitude aircraft imagery. Visual interpretation of July LANDSAT color composite data was deemed impractical (4). Digital analysis of CCT data proved more encouraging (2). Subsequent digital analysis using RSI's K-class package in conjunction with NASA's DIRS program and a CALCOMP plotter have allowed geometrically corrected LANDSAT-based aspen maps. The "aspen as aspen" classification is at least 50 percent better using LANDSAT data than is available from existing US Forest Service Maps of test township T4NR5E. In certain areas, LANDSAT digital analysis identified aspen groves which were not indicated on the high altitude interpretation.

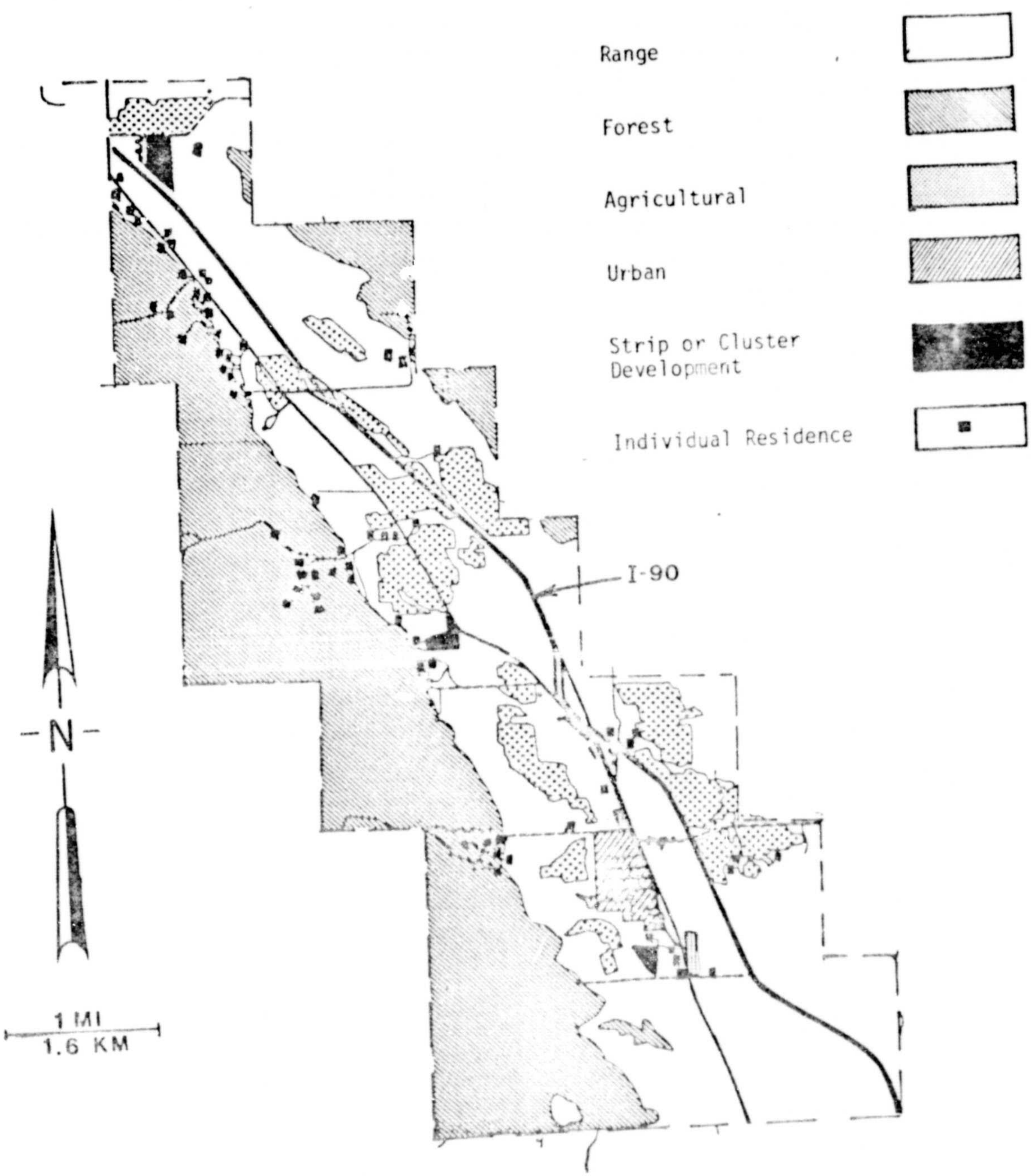

Figure 4. Landuse along same area as Figure 3, interpreted from 1974 aircraft data.

Mapclass

Considerable effort has been expended in the evaluation of entering remotely-sensed resource information into a computer-based data system. MAPCLASS, as the program is called, allows for manual coding of change-points rather than coding every cell in a grid system. The program also allows the computer to "overlay" and manipulate numerous combinations of data entered into the data base. Output via a Calcomp plotter permits maps to be generated at any desired scale.

The basic cell is 16.2 hectares (40 acres). This size was selected because it is small enough to obtain desired detail, but large enough to keep digitizing times reasonable. The grid system itself could have been based on a variety of coordinate systems. Two systems appeared to be the most practical: Latitude/Longitude and Range/Township. In selecting one of these two systems as the grid base, it was thought the Latitude/Longitude grid system would be easier to establish; however few South Dakotans are familiar with Latitude/Longitude as a ground reference system. South Dakota is subdivided into townships by a Range and Township grid system and because the nomenclature is widely used and understood, the decision was made to evaluate a data-base grid system based on Range and Township lines. A 1:250,000 base map of the Belle Fourche basin was prepared from 1:250,000 USGS Quadrangle maps. Based on Range correction lines and adjusted township lines, the basin was divided into eight sections varying in size from eight to 30 townships (93.3 km^2, or 36 mi^2 per township) each. These eight sections are essentially square in themselves and are each the basis of an individual grid system. The digitizing grid system was generated

using the Calcomp plotter and associated software. With the grid system established, it remained to evaluate the digitizing procedure and the practicality of the results.

A variety of data have been entered into the MAPCLASS data base. Coded information include: soil association, slope, land use, subbasins, Black Hills National Forest Boundary, counties, Range-Township lines, and surface water. Demonstration overlays of the various data have been prepared for evaluation by state agencies. Cost information, based on coding and processing the above data sets, is being prepared for inclusion in a cost effective analysis by participating agencies.

FUNDS EXPENDED

Total funds expended through May 31, 1976: $86,440.14. This does not include costs incurred by state agency participants as they invoice on a quarterly basis.

DATA USE (as of May 28, 1976):

Value of Data Allowed - $15,144.00

Value of Data Ordered - $11,316.00

Value of Data Received - $9,368.00

AIRCRAFT DATA

High and low altitude aircraft imagery have been used extensively as a ground truth supplement for surface water, land use, and aspen management studies. The aircraft data have been used as primary remote sensing data sources for floodplain mapping and Level II landuse mapping. Cloud conditions over certain ground-truthed areas, previously designated as intensive study sites (3), has necessitated reliance on high altitude aircraft imagery as a data base.

PROGRAM FOR NEXT REPORTING PERIOD

Further aspen analysis will quantify mapping accuracies. Additional land use interpretations using black and white LANDSAT imagery is planned. Development of input for DNRD's Belle Fourche River Basin Inventory is expected. Continued evaluation of DIRS is planned to continue investigation of relative accuracies involved. Cost effectiveness will be investigated. Input from State agencies is expected and will provide participitory information as well as recommendations and conclusions on the use of remote sensing data within each agency.

CONCLUSIONS

Continued LANDSAT analysis by and with participating state agencies has demonstrated to them the relative ease with which certain information can be obtained from the imagery. Comparisons with other available data, including the previous data source for a state-wide inventory, demonstrate the value of LANDSAT data as it relates to an accurate accounting of western South Dakota surface water. Mid June-July LANDSAT data appears an optimum source for Level 1 Landuse interpretations. Digital LANDSAT CCT analysis for aspen has produced maps 50 percent more accurate than any present typing maps of the test area. LANDSAT data have been successfully used in a drainage network mapping procedure which has resulted in an operational program for seven western South Dakota counties. Relatively simple and straightforward procedures have been employed in all analyses and the results demonstrate the potential value of the data.

REFERENCES

1. Van Wie, Peter, Maurice Stein, Edward Puccinelli, and Barbara Fields. "Digital Image Rectification System Preliminary Documentation." Information Extraction Division, Goddard Space Flight Center. November, 1975.

2. Schmer, F.A. and R.E. Isakson. "Investigation of Remote Sensing Techniques as Inputs to Operational Resource Management Models." Interim Type II Report to NASA. SDSU RSI-76 01, Remote Sensing Institute, South Dakota State University, Brookings, South Dakota 57006. March, 1976.

3. Schmer, F.A. and R.E. Isakson. "Investigation of Remote Sensing Techniques as Inputs to Operational Resource Management Models." Interim Type II Report to NASA. SDSU RSI-75 07, Remote Sensing Institute, South Dakota State University, Brookings, South Dakota 57006. June, 1975.

4. Schmer, F.A. and R.E. Isakson. "Investigation of Remote Sensing Techniques as Inputs to Operational Resource Management Models." Interim Type II Report to NASA. SDSU RSI-75 15, Remote Sensing Institute, South Dakota State University, Brookings, South Dakota 57006. December 1975.